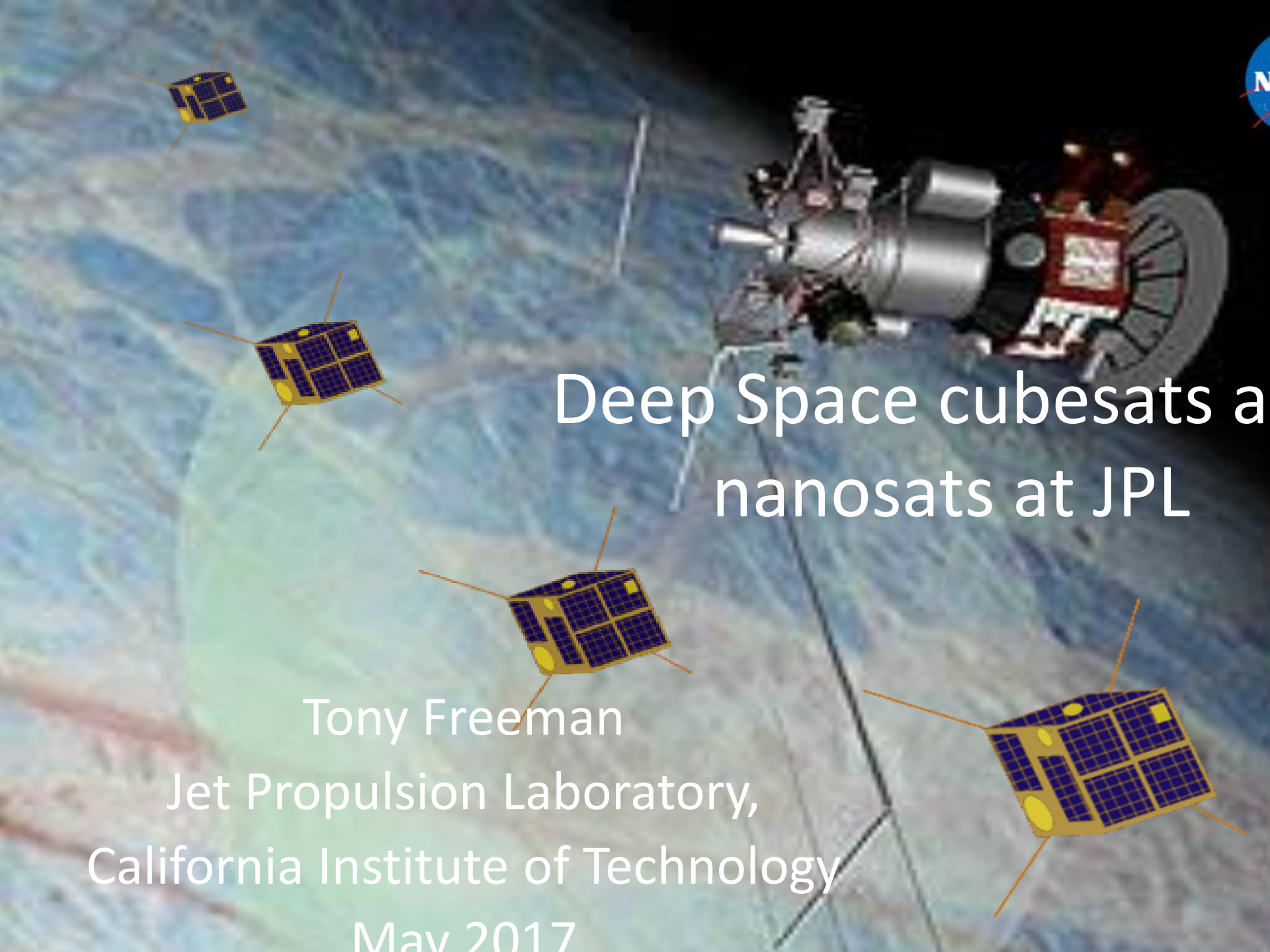


Deep Space cubesats a
nanosats at JPL

Tony Freeman
Jet Propulsion Laboratory,
California Institute of Technology
May 2017

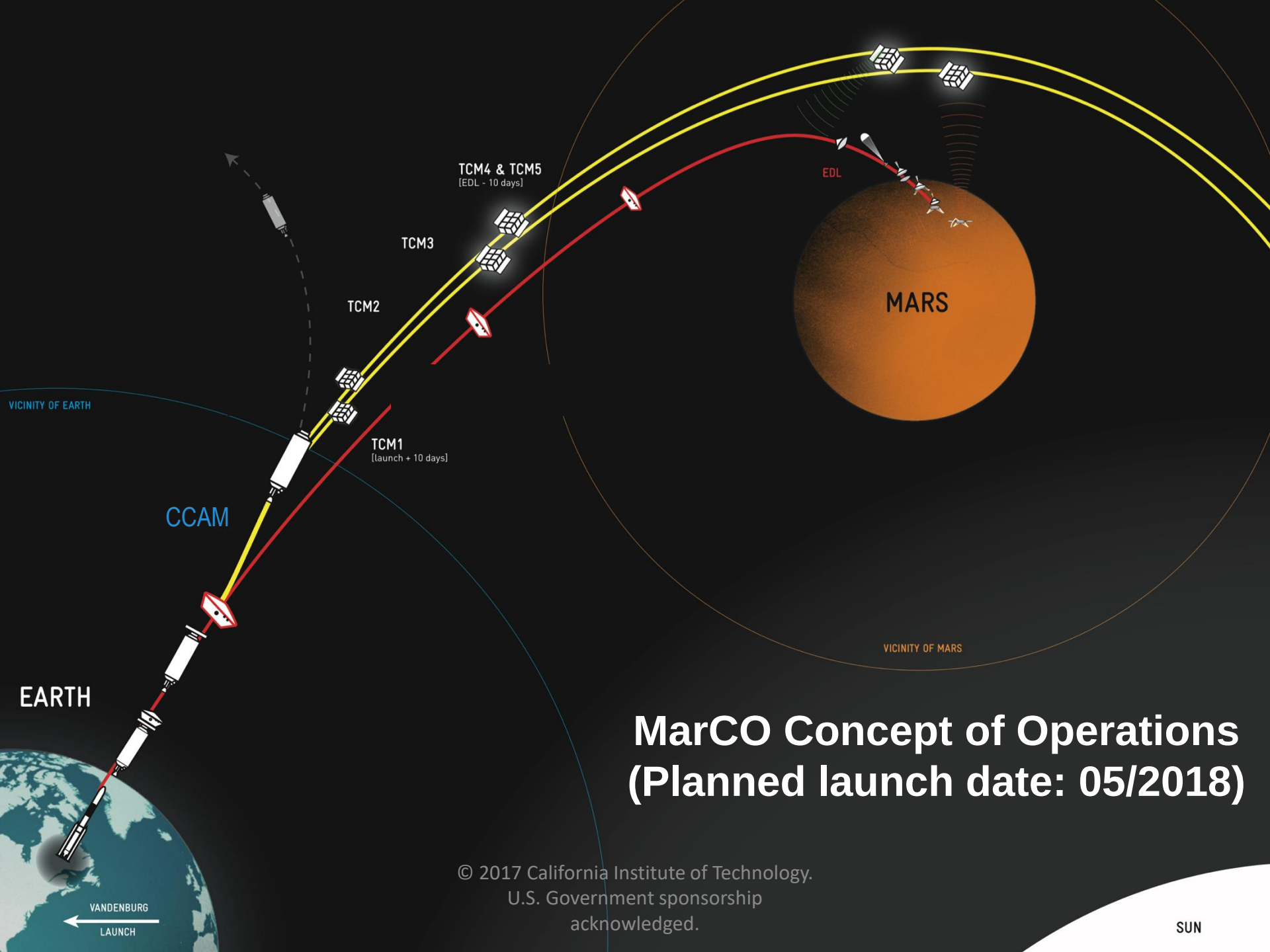
Cubesats and Nanosats at JPL

Overview

- JPL is known for its flagship missions to explore our solar system
- More recently, JPL has engaged with the cubesat/smallsat community to develop smaller missions for deep space exploration
- This talk will describe those activities

INSPIRE Flight Systems

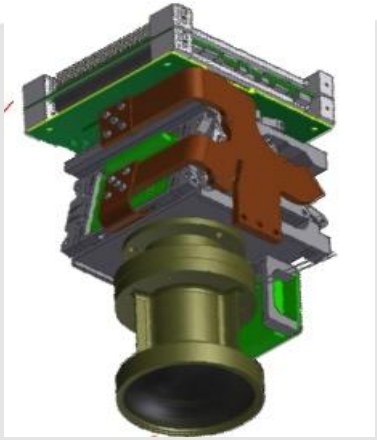
Jet Propulsion Laboratory
California Institute of Technology



MarCO Concept of Operations (Planned launch date: 05/2018)

Science Instrument Examples

HARP Imaging Polarimeter(3U)

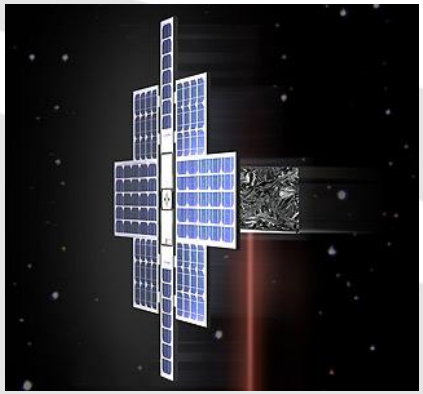


UMBC/SDL (2017)

RainCube radar (6U)

JPL (2017)

Lunar Flashlight (6U)
NIR laser



MSFC/JPL (2017)

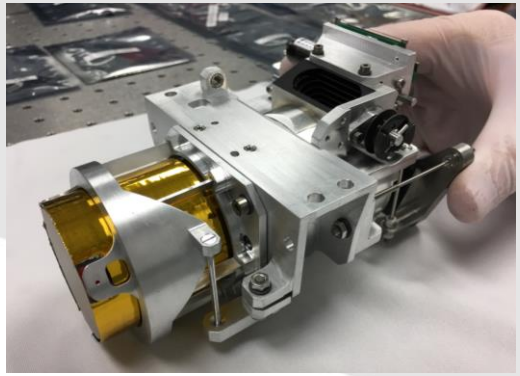
Mass Spectrometer (3U)

JPL (TBD)

LunarIceCube (6U)
IR spectrometer

GSFC (2018)

VSWIR-Dyson (2U)
spectrometer



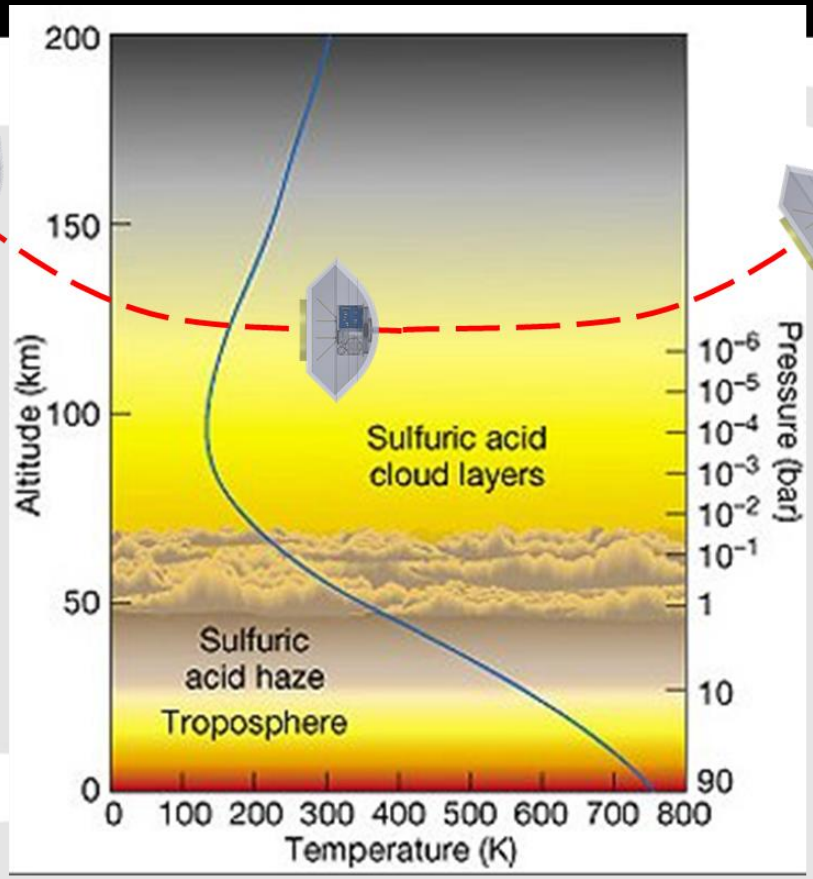
JPL (TBD)

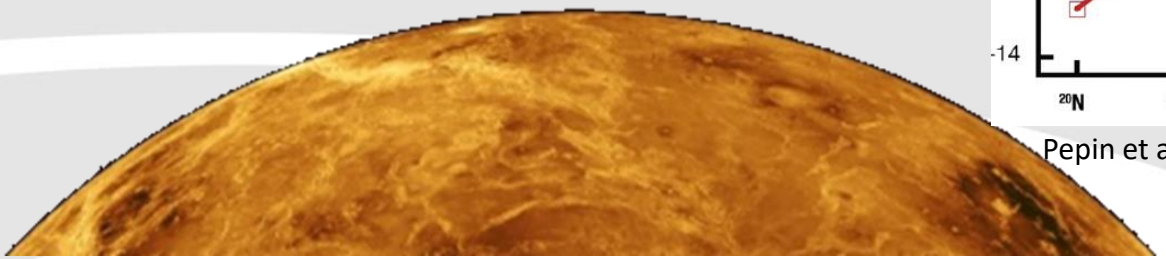
Cubesat-sized Instruments – 2012 and 2017

Technology	Selva* and Krejci, 2012	Freeman 2017	Justification
Atmospheric Chemistry Instruments	Problematic	Feasible	PICASSO, IR sounders
Atmos Temp and Humidity Sounders	Feasible	Feasible	
Cloud Profile and rain radars	Infeasible	Feasible	JPL RainCube Demo
Earth Radiation Budget radiometers	Feasible	Feasible	SERB, RAVAN
Gravity Instruments	Feasible	Feasible	Need a demo mission
Hi-res Optical Imagers	Infeasible	Feasible	Planetlabs
Imaging microwave radars	Infeasible	Feasible	Ka-Band 12U design
Imaging multi-spectral radiometers (Vis/IR)	Problematic	Feasible	AstroDigital
Imaging multi-spectral radiometers (μWave)	Problematic	Feasible	TEMPEST,
Lidars	Infeasible	Feasible	DIAL laser occultation
Lightning Imagers	Feasible	Feasible	
Magnetic Fields	Feasible	Feasible	InSPIRE
Multiple direction/polarization radiometers	Problematic	Feasible	HARP Polarimeter
Ocean color instruments	Feasible	Feasible	SeaHawk
Precision orbit	Feasible	Feasible	CanX-4 and -5
Radar altimeters	Infeasible	Feasible	Bistatic LEO-GEO
Scatterometers	Infeasible	Feasible	GPS refl. (CyGNSS)

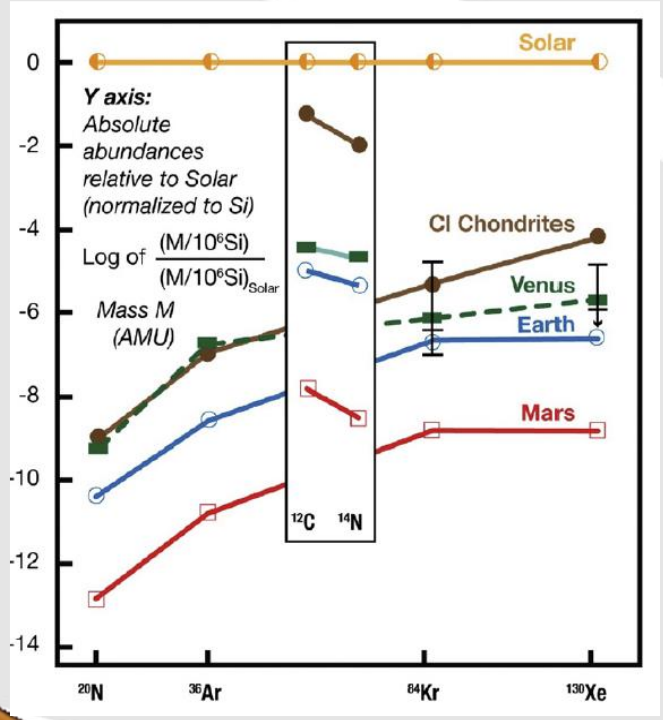
Cupid's Arrow (Venus)

Probe dips down to 120km





- Recent award of NASA funding to mature this mission concept
- PI: Christophe Sotin, JPL



Pepin et al., 1991; Chassefiere et al., 2012)

Other Smallsat Studies

- JUpiter MagnetosPheric boundary ExploreR (JUMPER)
- Small Next-generation Atmospheric Probe for clouds of Uranus (SNAP)
- Phobos and Deimos Cubesat Explorer (Chariot)

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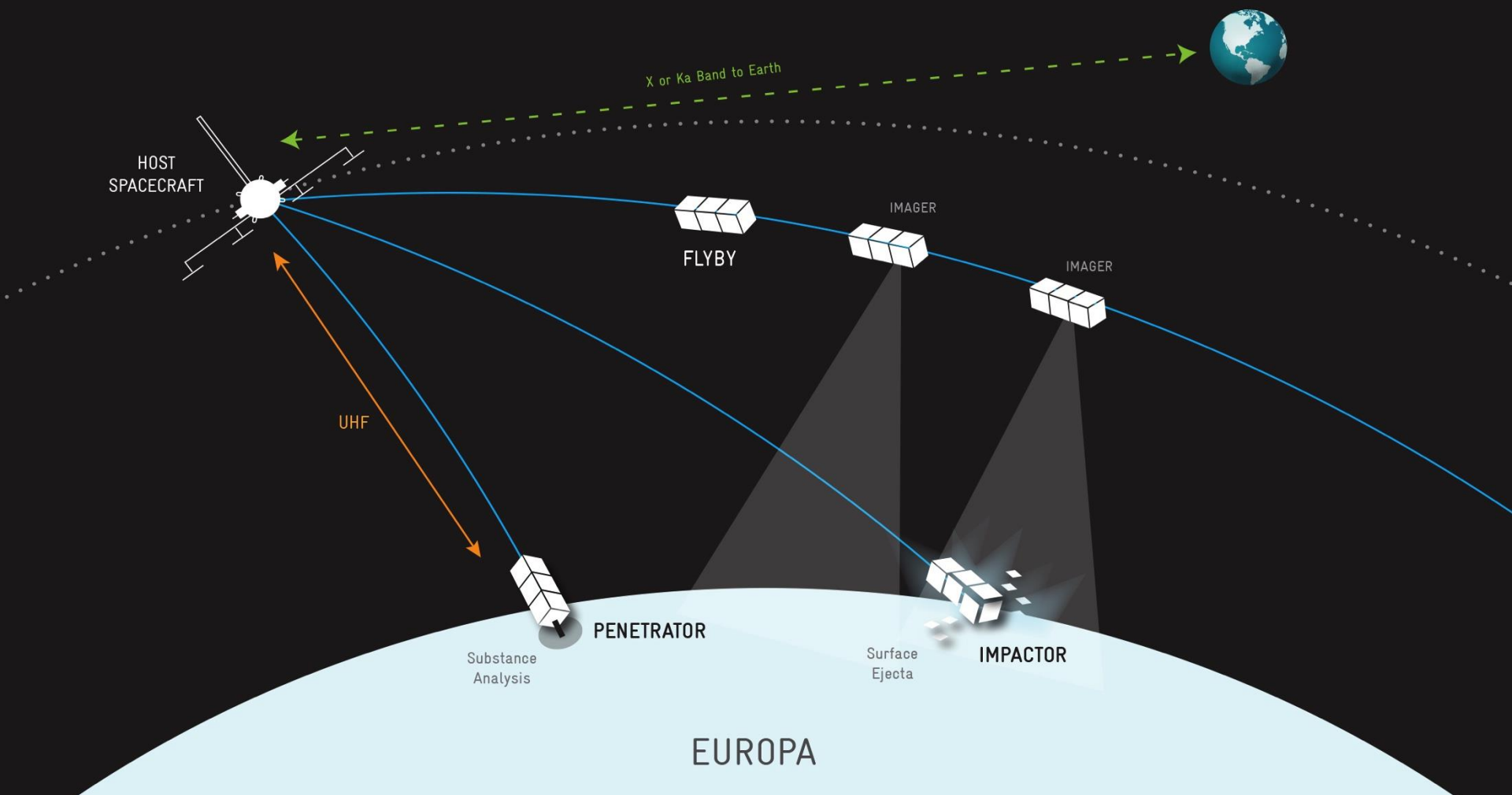
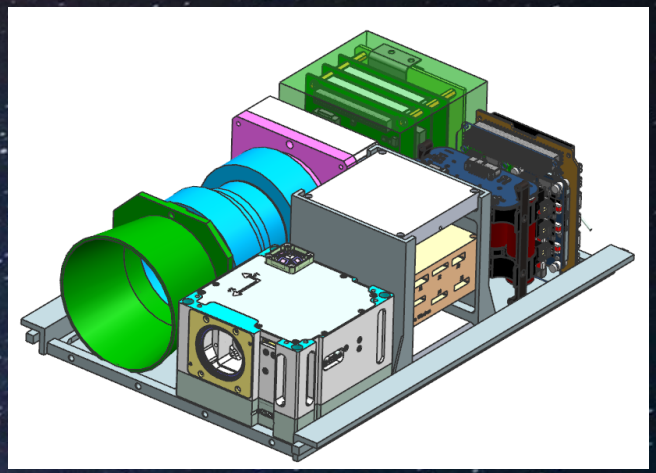
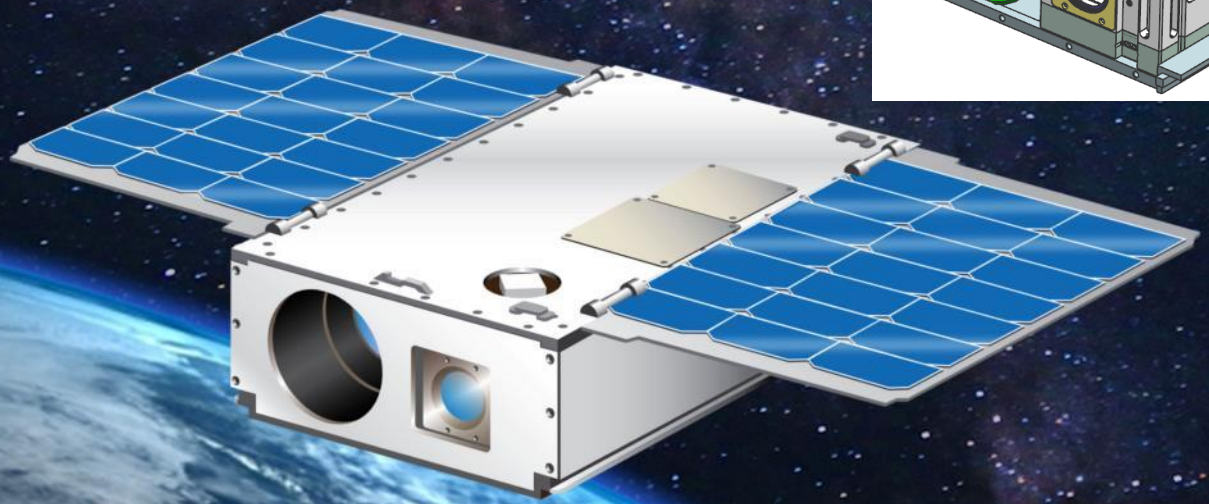
ExCSITE

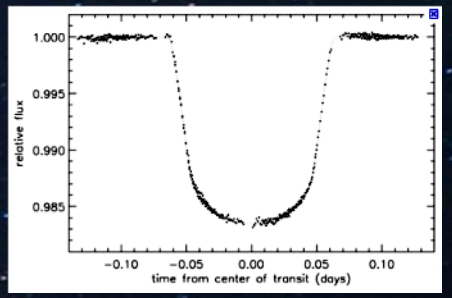


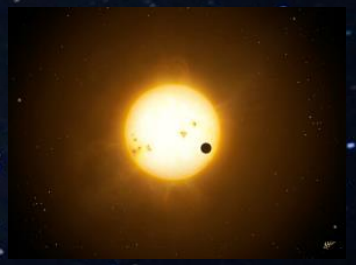
SPACECRAFT FORMATION	12 CUBESATS	FLYBY	DEPLOYMENT TRAJECTORY	HOST DEPLOYMENT	JOVIAN ENVIRONMENT	MISSION LIFETIME GOAL	3 YEARS

ASTERIA: Arcsecond Space Telescope Enabling Research in Astrophysics

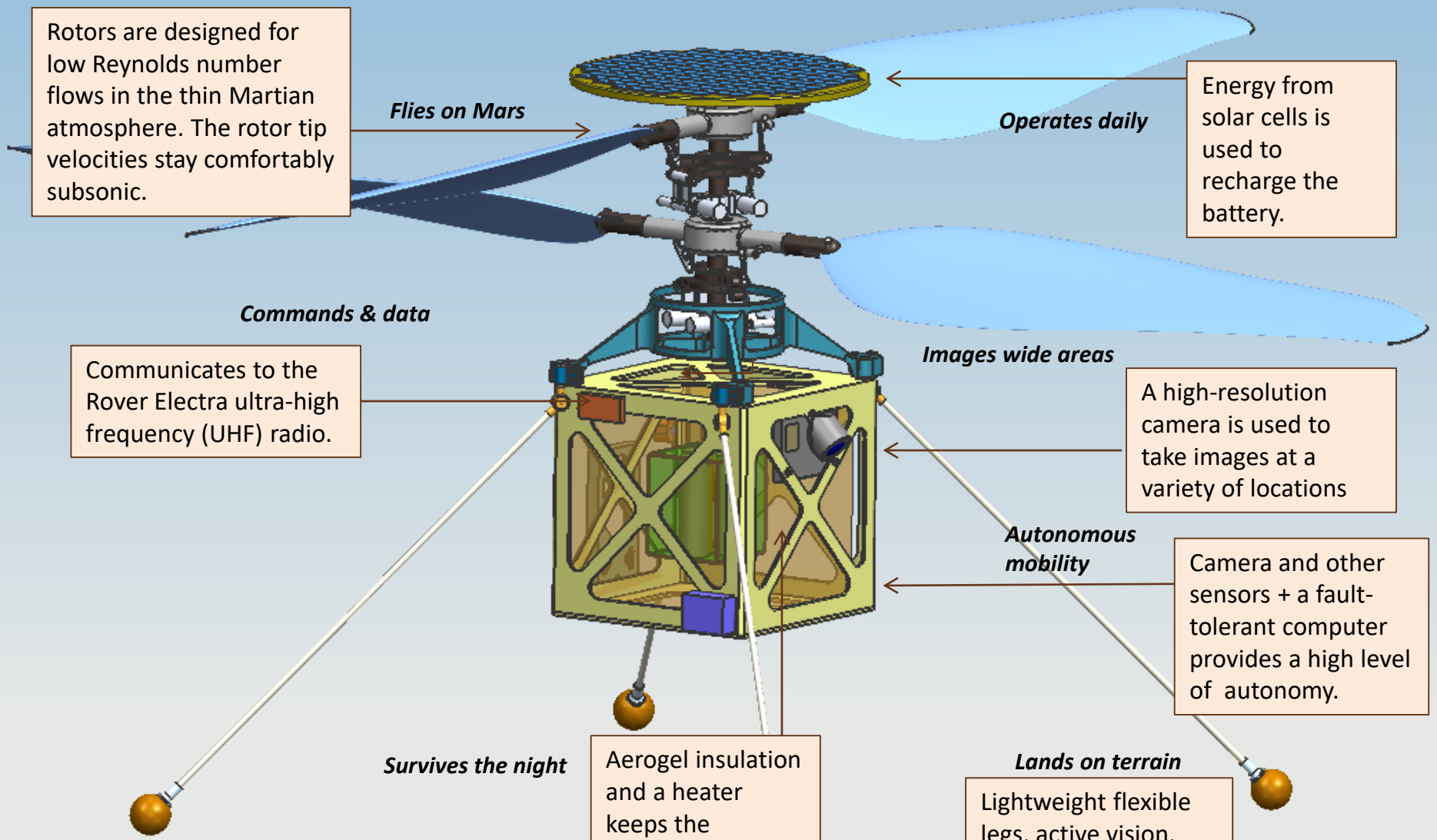








Mars Helicopter under Investigation



Rotors are designed for low Reynolds number flows in the thin Martian atmosphere. The rotor tip velocities stay comfortably subsonic.

Flies on Mars

Operates daily

Energy from solar cells is used to recharge the battery.

Commands & data

Communicates to the Rover Electra ultra-high frequency (UHF) radio.

Images wide areas

A high-resolution camera is used to take images at a variety of locations

Autonomous mobility

Camera and other sensors + a fault-tolerant computer provides a high level of autonomy.

Survives the night

Aerogel insulation and a heater keeps the batteries warm overnight.

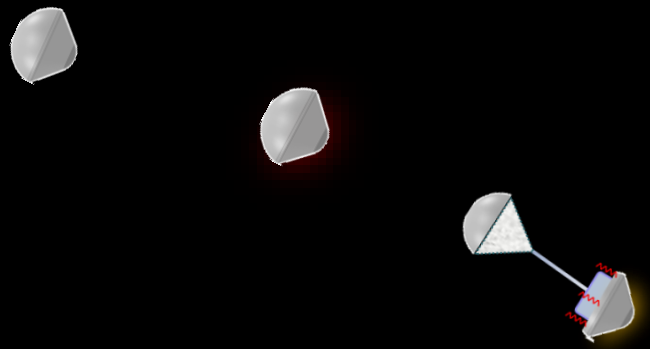
Lands on terrain

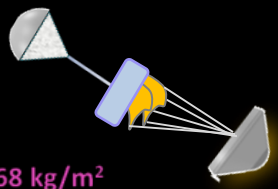
Lightweight flexible legs, active vision, and an altimeter for safe landing on terrain.

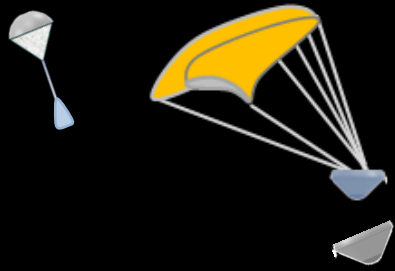
Jet Propulsion Laboratory
California Institute of Technology

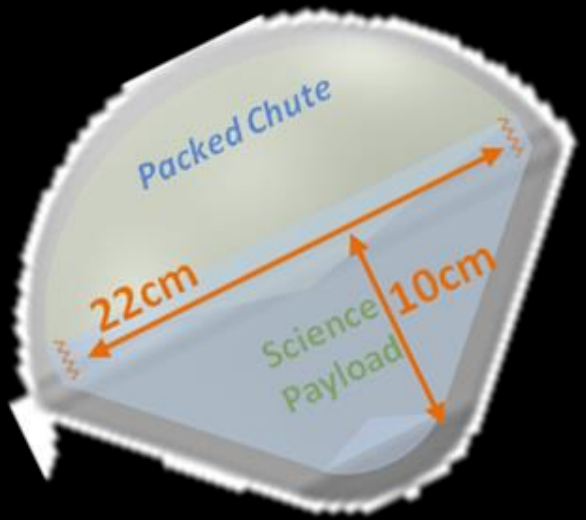
MarsDrop

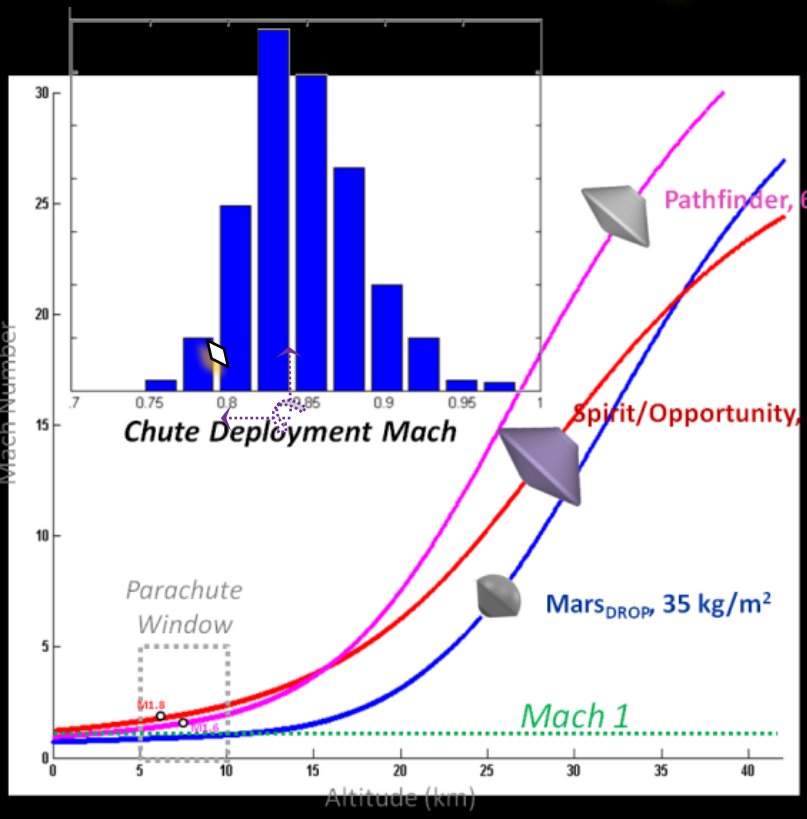
AEROSPACE











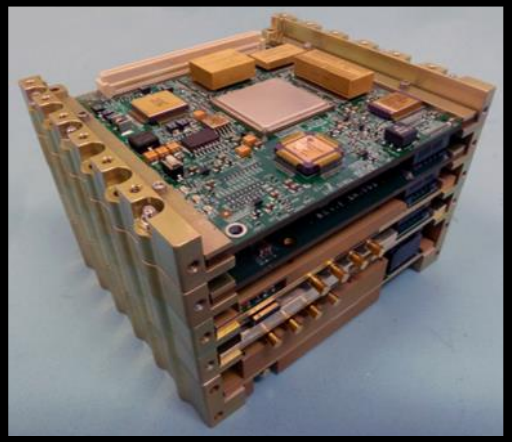
- Cubesat avionics enable insitu science at multiple landing sites

Courtesy Rob Staehle, JPL

MARS DROP

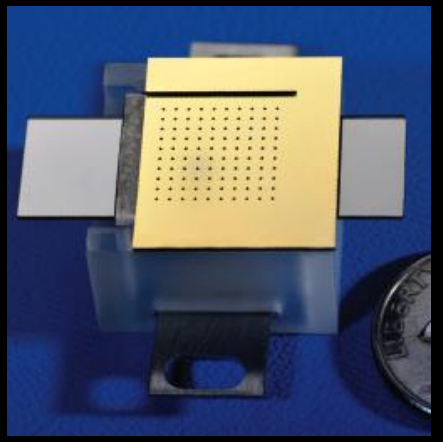
JPL Technologies and Standards

Deep SpaceTransponder



Deployable Reflector

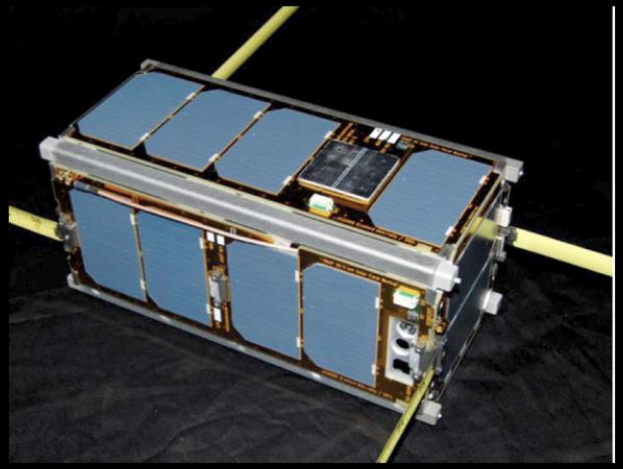
Micro-Electric Propulsion



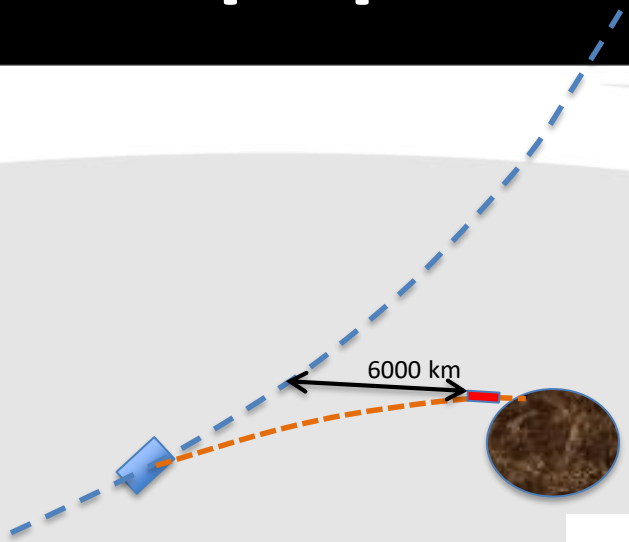
DSN Communications and Navigation Protocols

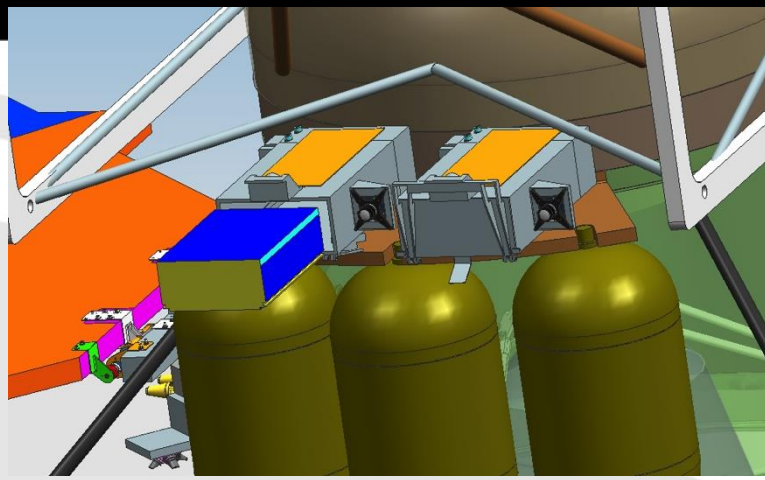
OnBoard Data Reduction

Low Mass Radio Transponder

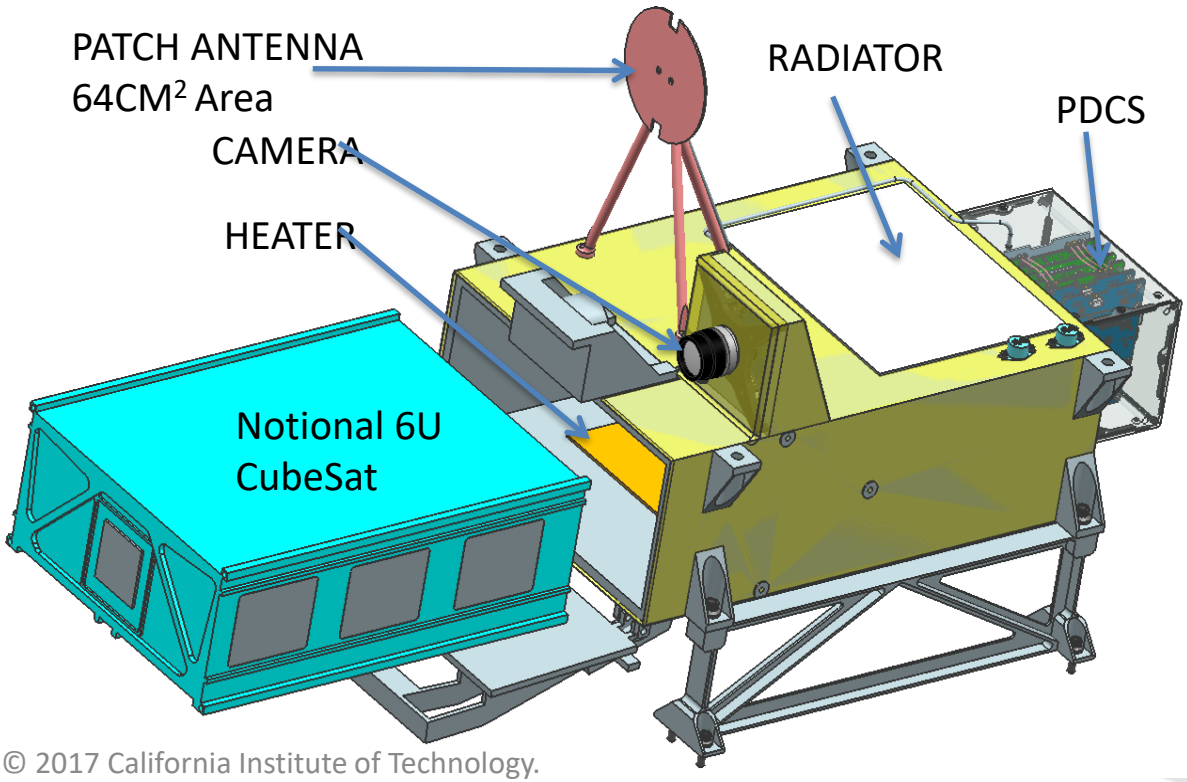


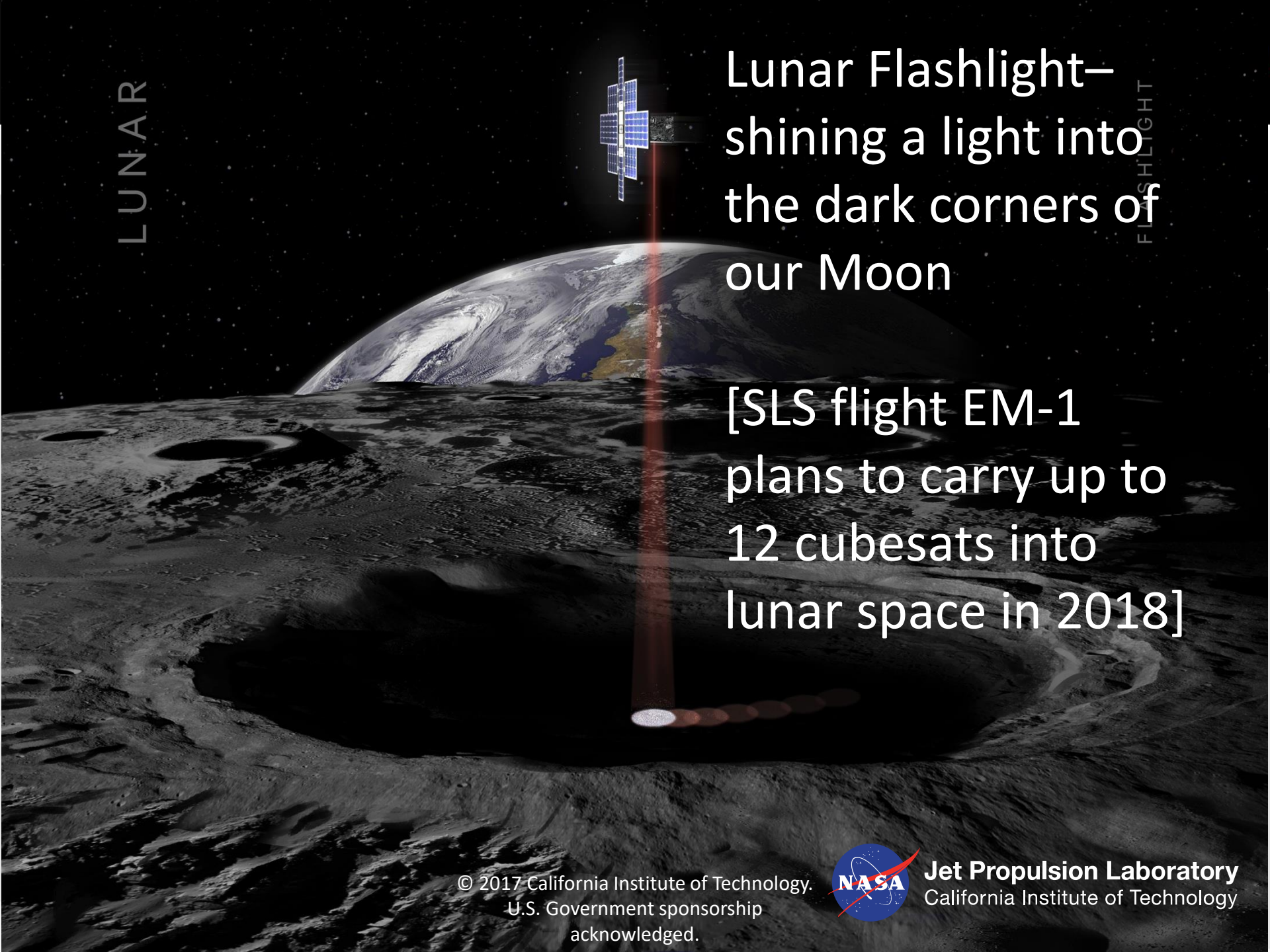
Deep Space P-POD Concept





Need for a "standard" communications, storage & deep space deployment system for small satellites





Lunar Flashlight– shining a light into the dark corners of our Moon

[SLS flight EM-1 plans to carry up to 12 cubesats into lunar space in 2018]

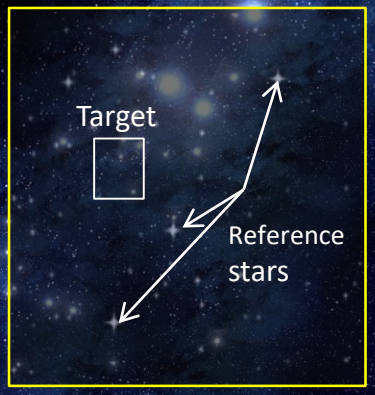
Jet Propulsion Laboratory
California Institute of Technology

NEAScout

Close Proximity Science
High-resolution imaging,
10 /px GSD over >30% surface
SKGs: Local morphology Regolith properties

JPL IntelliCam (Updated OCO-3 Context Camera)

NEA Reconnaissance
<100 km distance at encounter
50 cm/px resolution over 80% surface
SKGs: volume, global shape, spin properties, local environment



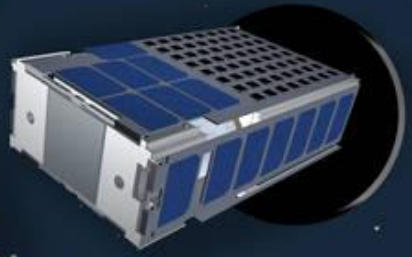
Target Detection and Approach:
50K km, Light source observation
SKGs: Ephemeris determination and composition assessment (color)

Courtesy: J. Castillo-Rogez, JPL

EXPLORATION MISSION-1: LAUNCHING SCIENCE & TECHNOLOGY SECONDARY PAYLOADS

13 CUBESAT EXPLORERS

GOING TO DEEP SPACE WHERE FEW CUBESATS HAVE EVER GONE BEFORE.



ORION STAGE ADAPTER

SUPPORTS BOTH PRIMARY MISSION AND SECONDARY PAYLOADS

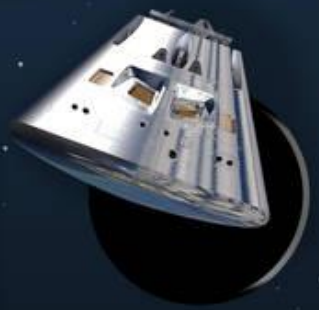
1

PRIMARY MISSION

TESTING SLS AND ORION

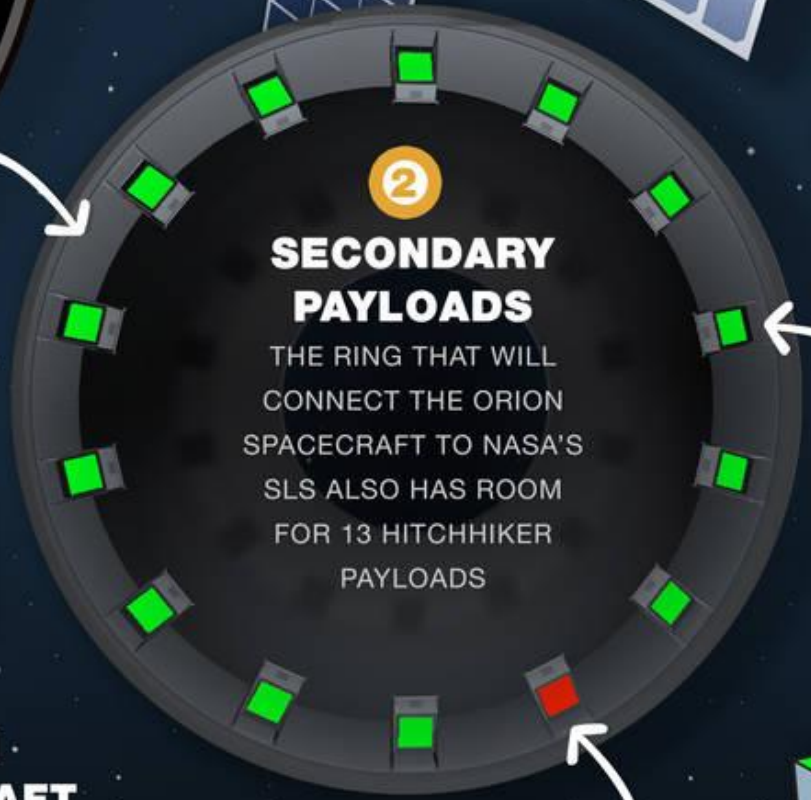
SPACE LAUNCH SYSTEM (SLS)

LIFTS MORE THAN ANY EXISTING LAUNCH VEHICLE



ORION SPACECRAFT

TRAVELING THOUSANDS OF MILES BEYOND THE MOON, WHERE NO CREW VEHICLE HAS GONE BEFORE



2

SECONDARY PAYLOADS

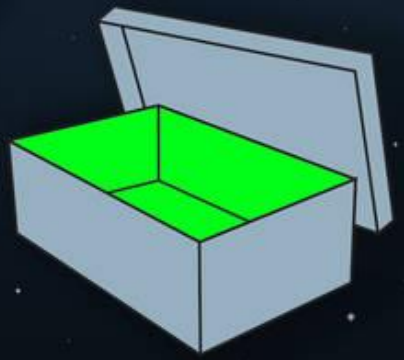
THE RING THAT WILL CONNECT THE ORION SPACECRAFT TO NASA'S SLS ALSO HAS ROOM FOR 13 HITCHHIKER PAYLOADS

SHOEBOX SIZE

PAYLOADS EXPAND OUR KNOWLEDGE FOR THE JOURNEY TO MARS

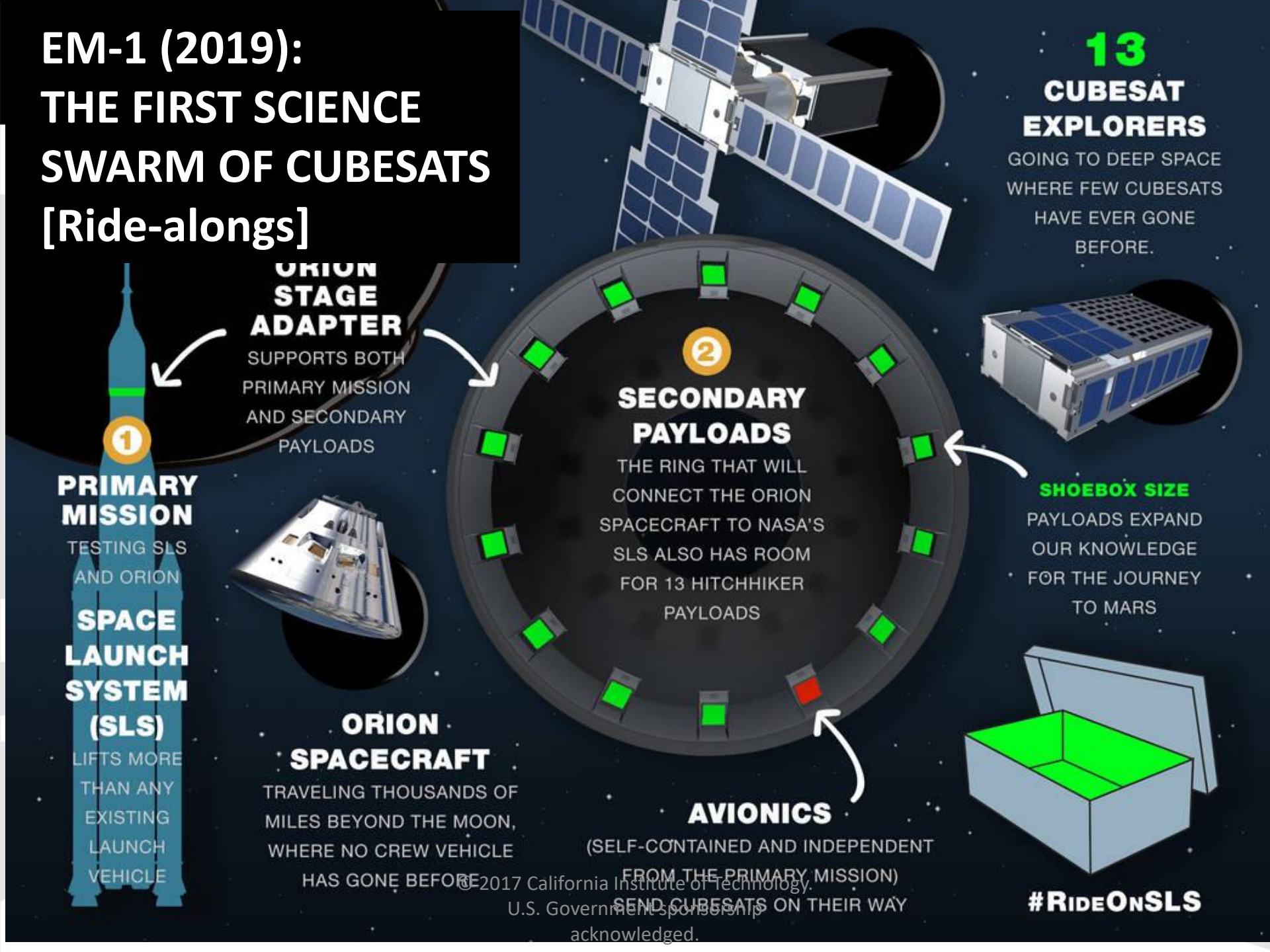
AVIONICS

(SELF-CONTAINED AND INDEPENDENT FROM THE PRIMARY MISSION) SEND CUBESATS ON THEIR WAY



#RIDEONSLS

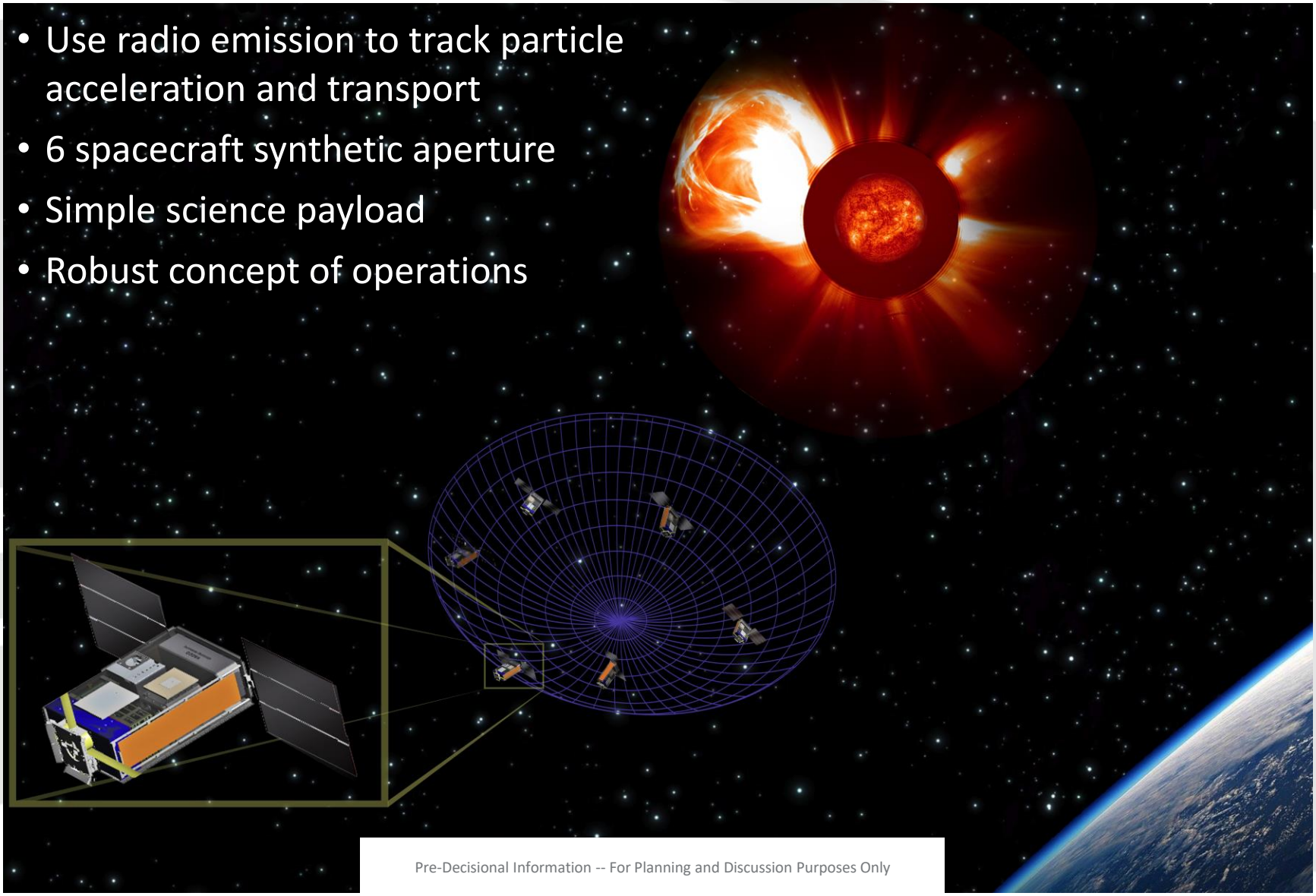
EM-1 (2019): THE FIRST SCIENCE SWARM OF CUBESATS [Ride-alongs]



Sun Radio Imaging Space Experiment

Mission Concept

- Use radio emission to track particle acceleration and transport
- 6 spacecraft synthetic aperture
- Simple science payload
- Robust concept of operations



Summary

- JPL has a healthy portfolio of science-driven Smallsat/cubesat flight projects
- We have a full pipeline of new mission concepts in development

- Visit our web site at:

www.jpl.nasa.gov/cubesat/